3D Representations of Cardiac Devices

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Introduction

What I set out to do during this project was to show how it is possible to render real human hearts and heart devices using specialized software, show how the devices can be implanted in the heart models, and also print the models to be given to medical professors or students while experimenting with the material used to print the models.

Using 3D computer generated replicas of human hearts could help advance human understanding of heart anatomy. Models can help medical students learn various heart anatomies of normal and defective hearts of real patients. They can help surgeons to plan beforehand so they can avoid obstacles and complications.

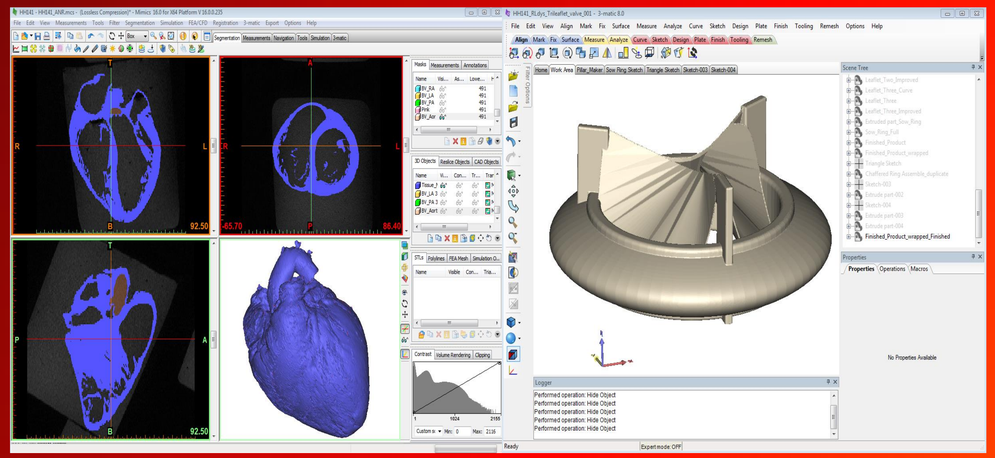

Fig. 1: Mimics Heart Model

Fig. 2: 3-Matic Trileaflet Heart Valve

Methods

Making the Heart

Human Hearts specimens are first imaged using MRI and CTs. This produces sequential image stacks of the heart that are then processed using Materialize's Mimics software suite. The static MRI scans of the heart produce incredibly detailed images, down to 100 um in resolution. This is FAR more resolution than can be had through in situ imaging (i.e. a living patient).

The images are essentially a map of pixels which represent the relative density of tissue at a given location. Mimics was then used to define areas of high density as physical tissue and areas of low density as empty space. Those areas which belong to the tissue are designated or "Masked" to occupy space in the 3D model and using this process with the Mimic's software packages it was possible to reconstruct the whole heart. [Fig. 1]

Making the Devices

The heart model is loaded to a biological CAD software called 3-matic. With 3-matic various CAD design models for several different biological cardiac devices were constructed. Using a catheter as a base design it was possible to reconstruct it as a 3D model [Fig. 3].

The flexible sections of catheters and leads implanted in the heart had to be traced out with lines and then a circle was extruded using the lines as a guide [Fig. 5]. A CAD design for a generic mechanical bileaflet heart valve was provided by the Medical Device Center [Fig. 4]. A generic trileaflet valve was made from approximated measurements from images [Fig. 2]. The heart model was manipulated and combined with the valve models to show how they appear when sown into the walls of the heart [Fig. 6]. Once digitally implanted, the models could be printed [Fig. 7].

Heart Valves

Valves are replaced for mainly two reasons: The valve doesn't close all the way allowing backward flow, or won't open fully holding back flow[2]. The Human Heart has four valves: Mitral, Tricuspid, Aortic and Pulmonary. The most common valves replaced in adults are the mitral and aortic valves but replacement of the pulmonary and tricuspids valves do occur.

The two main replacement valve types are mechanical valves or tissue valves[2]. Mechanical valves are constructed of mostly either stainless steel or titanium and generally last longer while donated tissue valves are from deceased humans or animals like pigs or cows.

Both valves come with drawbacks

Mechanical valves function typically for about 8-20 years before needing to be replaced[2]. The major drawback is that recipients will need blood thinner medication for the rest of their life. Also some patients complain of hearing clicking sounds from the mechanical valve in their chest which can be troubling or reassuring for them. Typically patients 65 and younger opt for mechanical valves[3].

Tissue Valves function typically for about 12-15 years, but they do degrade faster in younger patients but don't usually need blood thinner medication.

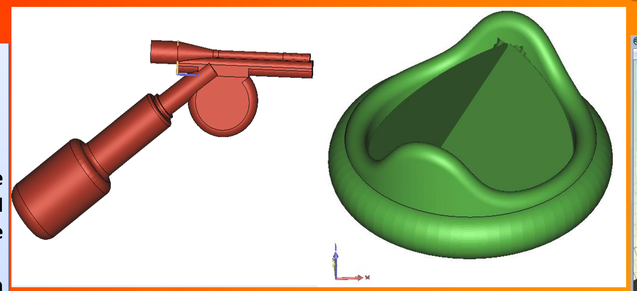

Fig. 3: Catheter Ring Model, Fig. 4: Bileaflet Heart Valve

Pacing Leads and Catheters

Catheter delivered pacing leads are the live ends of most pacemaker systems which keep millions of people alive through a variety of pacing modalities and configurations depending on the patient's particular cardiac malady. Common indications include chronological incompetence of the SA/AV node, sick AV node, AF, Bradychardia, tachacardia, and an array of cardiac arrhythmias. For which, various physical configurations of the pacing system : bi-ventricular, atrial, ventricular, dual chamber are implanted to fix[1]. The catheters that deliver those leads are a frequently used device for various different types of heart operations.

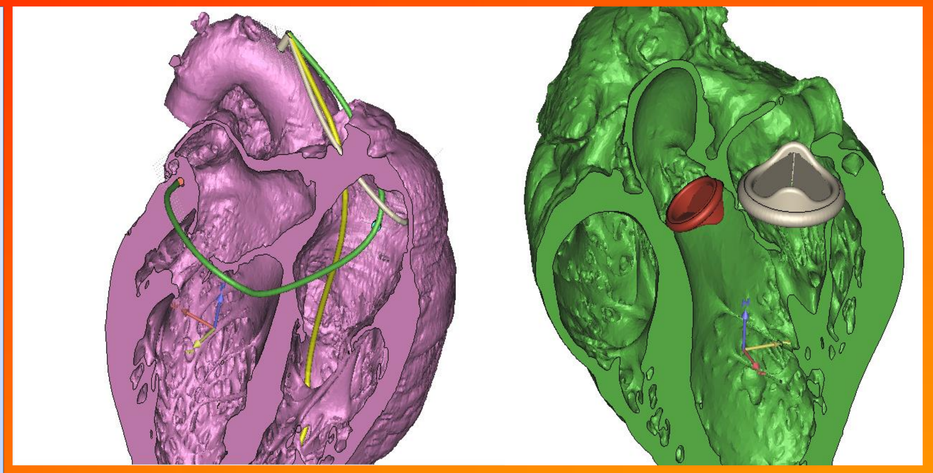

Fig. 5: Heart Model with Leads Placed, Fig. 6: Heart Model with Valves Placed

Results

The end result is a set of medical devices digitally modeled and implanted in real human cardic anatomy, and made tangible through 3D pritinting technology. I was able to make both a heart model as well as several replica medical devices, and the lab has begun to print them [Fig. 8]. The technology exists to print these models with different materials to use when printing the hearts to make more realistic models as plans to be done later. The models are also to be made available for teaching and instruction at the University of Minnesota in the coming years.

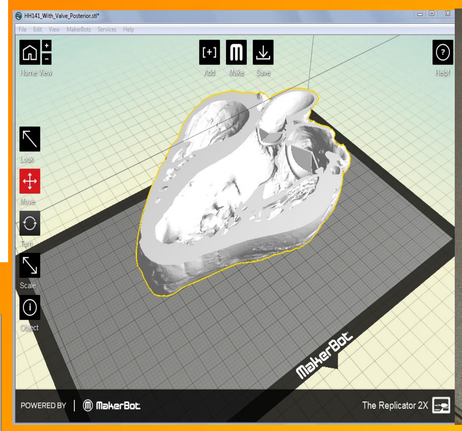

Fig. 7: Half of Heart in MakerWare

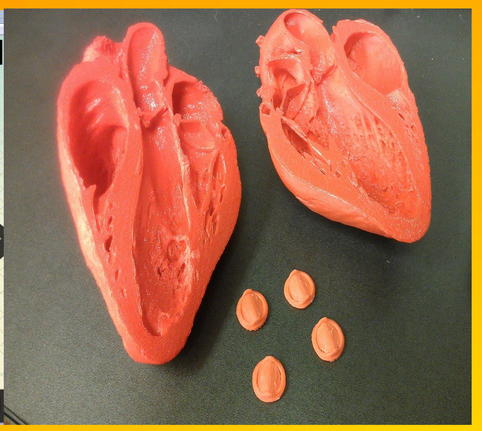

Fig. 8: Printed Heart and Heart Valves

Acknowledgements & References

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[1]Iaizzo, Paul. *The Visible Heart Laboratory*. Visible Heart Lab. June 24, 2014. Web. July 29, 2014. <http://www.vhlab.umn.edu>

[2]*MedlinePlus*. National Institute of Health. June 6, 2014. Web. July 29, 2014. <http://www.nlm.nih.gov/medlineplus/ency/article/002954.htm>

[3]*On-X Life Technologies Inc*. 2013. Web. 23 Aug, 2013. <http://www.onxlti.com/message-to-patients/tissue-or-mechanical-heart-valve/>